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KENNEBEC: A NEW POTATO VARIETY RESISTANT TO LATE BLIGHT, MILD MOSAIC, AND NET NECROSIS

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Late blight, caused by *Phytophthora infestans*, is so common in the sections of the United States best suited for potato culture and causes such heavy losses that it is often referred to as "the potato disease".

It is true that this disease can be controlled to a large extent by careful spraying with certain fungicides. However, despite the facts that control measures are being practiced more generally than ever, that spray equipment has been improved, and that spray programs have been more faithfully carried out, large losses continue to occur. In some seasons and in certain sections the disease causes very little damage, but all too frequently the loss amounts to millions of bushels. Epidemics occurred in the United States in 1927, 1928,

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1932, 1936, 1938, and 1943. The loss in 1928 was estimated at 31 million bushels; in 1932, at 9,230,000 bushels, of which 9,058,000 bushels were lost in Maine. A blight-resistant variety would greatly reduce such losses and eliminate a large part of the cost of control measures.

Breeding for resistance to late blight in the potato began in the United States nearly 100 years ago. A relatively large number of varieties were produced. Some of them are grown commercially to the present day and have been noted for their high yields and good cooking quality but none of them showed any resistance to late blight. Breeding for resistance to this disease seemed to have been abandoned during the latter part of the nineteenth century, and methods of controlling blight by spraying with fungicides (mostly bordeaux mixture) were developed.

The breeding mode of attack was not again emphasized in the United States until potato breeding was actively undertaken by the United States Department of Agriculture in 1910. According to Clark *et al*¹, the only disease resistance sought at the time was to the late blight fungus. This work had not progressed very far, however, when it became evident that the virus diseases had to be given the chief consideration, and it was not until the present National Potato-Breeding Program was under way that emphasis could be placed once more on breeding for resistance to late blight. The first indication of resistance observed in the present program was found in a cross of the two susceptible varieties, Chippewa and Katahdin. This cross was tested in 1932 for blight resistance in the field. Many of the seedlings were very susceptible, a few were intermediate in their reaction, but none of them showed the highest type of resistance. One of the best of these was eventually named Sebago and distributed to growers. The program continued with crosses in which intermediate types were involved such as President, Ackersegen, and Sebago. Many of the resulting intermediate types could be considered commercially resistant, but none of the selections was found superior in other characters to Sebago, which was already in commercial production. Most of them were too late maturing to be of value. However, Calrose, which shows an intermediate resistance to late blight, was produced from a cross of Ackersegen x Katahdin. This variety is being grown to a limited extent in California.

¹Clark, C. F., and Stevenson, F. J. 1935. The Katahdin, Chippewa, and Golden Potatoes. U. S. Dept. Agr. Circ. 374.

The next step in advance was the introducing of the German *W* races. Seeds of these were obtained from K. O. Müller, Berlin-Dahlem; Germany. Seedlings grown from this material were tested in the field at Presque Isle, Maine in 1934, 1935, and 1936. Many of them did not become infected with late blight, although Green Mountain and other susceptible varieties were practically killed by the disease 30 to 40 days before they had time to mature. The seedlings related to the *W* races contributed two characters of great importance to the breeding program: much higher type of resistance to late blight than that found in President and in the other intermediates, and genes for early maturity. However, none of them approached the commercial varieties in yield or market quality. A few of the best of them were crossed with Earlane, Katahdin, and Seedling 336-18. Selections from cross number 96 (German No. 3895-13 x Earlane) were among the best of this series of crosses. Of these, 96-44 and 96-56 are highly resistant, if not immune to the common races of blight in Maine and are early and self-fertile. These two approached early commercial varieties in yield and cooking quality but they were inferior in yield to such standard varieties as Green Mountain, Chippewa, and Katahdin. Another series of crosses were then made using as parents the best selections from cross No. 96 and some of the highest-yielding varieties and seedlings available. From this second series B 70-5 was obtained. It was a selection from the cross B 127 x 96-56. B 127 was a Beltsville selection from a cross of Chippewa x Katahdin and at one time was considered for distribution to growers in Maryland. Seedling 96-56, from the cross German No. 3895-13 x Earlane, was one of the first seedlings produced by the United States Department of Agriculture that combined blight resistance in both vines and tubers with mild mosaic resistance and early maturity.

During the winter of 1940, cross No. B 70 was made in the greenhouses of the Plant Industry Station, Beltsville, Maryland. The seedlings were grown in the same greenhouses in the fall of 1940 and the tubers sent to Presque Isle, Maine, for increase in 1941. A number of selections were made and since that time they have been tested for horticultural characters and reactions to various diseases. B 70-5 has proved to be the best of this group, although several others were close competitors.

The pedigree of B 70-5 follows:

Kennebec U.S.D.A. Seedling No. B 70-5	{	96-56	{ Earlane 3895-13
		B 127	{ Katahdin Chippewa

DESCRIPTION

Kennebec

Plants—Large, spreading; stems thick, prominently angled; nodes slightly swollen, green; internodes green; wings slightly waved, green; stipules large, green, and scantily pubescent; leaves long, broad, close, and dark green; midribs green and scantily pubescent; primary leaflets ovate, large, four pairs, mean length 64.70 ± 0.38 mm. (2.55 inches), mean width 38.27 ± 0.44 mm. (1.51 inches), index 59.32 ± 0.49^2 ; petioles green; secondary leaflets many, between primary leaflets; tertiary leaflets few to none; inflorescence medium to little branched; leafy bracts none; peduncles medium long, green, and scantily pubescent; pedicels medium to long, green, and scantily pubescent.

Flowers—Calyx-lobe tips long, green, and scantily pubescent; corolla medium in size (32 to 34 mm. diameter), white; anthers orange yellow; pollen abundant, good quality; style straight; stigma globose, multilobed, green.

Tubers—Elliptical to oblong, mean length 90.04 ± 0.56 mm. (3.54 inches)³; mean width 72.22 ± 0.24 mm. (2.84 inches)³; mean thickness 57.68 ± 0.35 mm. (2.27 inches)³; index of width to length, 80.59 ± 0.74^4 ; of thickness to width, 80.10 ± 0.67^5 ; of thickness to length, 64.49 ± 0.70^5 ; skin smooth, self-colored, creamy buff; eyes shallow, of

²Calculated by dividing the width of each of 100 leaflets by the length and multiplying the average of these ratios by 100. The leaflets were taken from the fourth leaf from the top of a stem, one leaflet, the distal left lateral, being taken from each leaf. Since the potato leaflet is asymmetrical the length was determined by taking the average of the measurements from the apex to the base of each respective lobe. This is a modification of the method described in Salaman, R. N.: *Potato Varieties*, pp. 163-170. Cambridge, 1926.

³Average of measurements of 100 tubers each weighing approximately 8 ounces (223-233 gm.).

⁴Calculated by dividing the width of each of one hundred tubers by the length and multiplying the average of these ratios by 100. The data used for calculating the index were taken from the same measurements as those used to designate the dimensions of the tubers.

⁵Based on the measurements of the same tubers as those used for determining the width-to-length index, using the same methods of calculation.

same color as skin; eyebrows medium long, curved, medium prominent; flesh white; sprouts creamy white when developed in the dark; maturity late.

CHARACTERISTICS

Kennebec is a vigorous, fast-growing, high-yielding, late-maturing variety. In tests for 5 years at Presque Isle, Maine, it outyielded Green Mountain by an average of 19 bushels of U. S. No. 1 potatoes per acre. In the same tests it outyielded Katahdin by 97 bushels per acre, Chippewa by 41, and Sebago by 79. It produced also the highest percentage of U. S. No. 1 tubers as shown in table 1.

The specific gravity data for these tests show in table 2 that B 70-5 does not have as high dry-matter content as Green Mountain but has averaged higher than Katahdin, Chippewa, or Sebago. It has been judged as very good to excellent for either baking or boiling by a relatively large number of people who have tested it for cooking quality.

In 1946 and 1947 tests were made of Kennebec in comparison with standard varieties at several places in Maine. The data for these tests are given in tables 3 and 4. Both the specific gravities and the yields of all varieties varied from place to place in both years. In 1946 all varieties were mealy as grown at Presque Isle, but none of those grown at Fort Kent would be in that class. On the other hand, the yields at Fort Kent far exceeded those of the plots at Presque Isle. In 1947 the specific gravity readings were comparatively low for all tests. Kennebec exceeded Green Mountain in average yield in five tests in 1946 and in four tests in 1947; however, Green Mountain was slightly higher in specific gravity than Kennebec.

The resistance of Kennebec to the common races of late blight is very high in both foliage and tubers. Under field conditions in the late blight test, where the vines were inoculated or sprayed with zoospores and where no commercial fungicides were used, the Kennebec variety has shown no late blight lesions for several years. The tubers, when harvested at an immature stage and sprayed with zoospores, showed a trace of late blight rot after a 2-week incubation period, as did the Sebago tubers also. In this test the tubers of the susceptible seedlings and Green Mountain checks were severely affected. In the 1946 yield test at Dover-Foxcroft, Maine, there was considerable blight rot in the tubers of susceptible varieties with large differences between the varieties. Sequoia showed approximately 38 per cent tuber rot; Green Mountain, 29 per cent; Sebago, 2 per cent; and Kennebec, none. Thus, Kennebec is

TABLE 1.—Yield and percentage of U. S. No. 1 tubers obtained from tests of the potato variety *Kennebec* in comparison with standard varieties at Presque Isle, Maine

Varieties	Yield of U. S. No. 1 Tubers per Acre					Percentage of U. S. No. 1 Tubers per Acre				
	1943	1944	1945	1946	1947	Mean	1943	1944	1945	1946
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Pct.	Pct.	Pct.	Pct.
Kennebec	615	375	433	442	523	478	97	99	96	99
Green Mountain	556	374	410	473	480	459	99	97	94	97
Katahdin	479	244	347	341	495	381	98	95	95	95
Chippewa	504	333	407	370	511	437	99	97	95	97
Schago	498	301	373	353	470	399	98	93	94	95
Difference for significance at 5-per cent level	63	33	60	54	88	28				

TABLE 2.—*Specific gravity tests of the potato variety Kennebec in comparison with standard varieties grown at Presque Isle, Maine*

Variety	Specific Gravity					
	1943	1944	1945	1946	1947	Mean
Kennebec	1.092	1.080	1.088	1.093	1.082	1.087
Green Mountain	1.100	1.086	1.095	1.099	1.091	1.094
Katahdin	1.087	1.077	1.081	1.093	1.081	1.084
Chippewa	1.079	1.073	1.076	1.080	1.073	1.076
Sebago	1.088	1.072	1.082	1.093	1.079	1.083
Difference required at 5-per cent level	.008	.006	.004	.003	.002	.003

superior to Sebago for blight resistance in the vines and is at least its equal for resistance in the tubers.

In the mild mosaic exposure tests the Kennebec has been highly resistant to the mild mosaic virus. As yet this disease has not been transmitted to the Kennebec after exposure for several seasons to 100-per cent-infected Green Mountains.

Plants of Kennebec showing leaf roll have been found in small numbers in the field, but the corresponding symptoms of net necrosis in the tubers due to current-season infection have never appeared in the tests. For 3 years Kennebec was exposed in 5-hill plots to leaf roll in the net necrosis exposure tests. Eventually its plants were infected with leaf roll, but net necrosis in the tubers was not evident. In 1947 four varieties, including Kennebec, were planted in 20-hill rows, replicated three times, adjacent to rows of Irish Cobbler infected 100-per cent with leaf roll. At harvest time these samples were stored under optimum conditions for the development of net necrosis symptoms in the tubers. In December they were examined and recorded as indicated in table 5.

TABLE NO. 5.—*Variety comparison for net necrosis resistance at Presque Isle, Maine, in 1947*

Variety	Total Tubers ¹	Total Netted ¹	Percentage Netted
	No.	No.	Per cent
Mohawk	177	131	74.0
Green Mountain	222	86	38.7
Sebago	218	22	10.1
Kennebec	194	0	.0

¹Total number for three replications.

TABLE 3.—Comparative yield and specific gravity of Green Mountain, Katahdin, Mohawk, Sebago, and Kennebec at five locations in Maine in 1946¹

Variety	Locations in Maine									
	Fort Kent ¹		Presque Isle		Patten		Hampden		Dover-Foxcroft	
	Specific Gravity	U. S. No. 1 Tubers per Acre	Specific Gravity	U. S. No. 1 Tubers per Acre	Specific Gravity	U. S. No. 1 Tubers per Acre	Specific Gravity	U. S. No. 1 Tubers per Acre	Specific Gravity	U. S. No. 1 Tubers per Acre
Green Mountain	1.076	Bu. 869	1.099	Bu. 473	1.086	Bu. 614	1.080	Bu. 342	1.083	Bu. 420
Katahdin	1.071	665	1.093	341	1.082	464	1.074	289	1.077	305
Mohawk	1.079	728	1.103	423	1.085	483	1.079	299	1.085	307
Sebago	1.076	728	1.093	353	1.080	565	1.071	267	1.082	410
Kennebec	1.072	810	1.093	480	1.086	559	1.074	445	1.084	550
										Bu. 544
										1.085
										1.079
										1.086
										1.080
										1.082
										1.082
										548
										465
										569

¹Four replications of 25 hills for each variety at each location were averaged.TABLE 4.—Comparative yield and specific gravity of Green Mountain, Katahdin, Mohawk, Sebago, and Kennebec in four locations in Maine in 1947¹

Variety	Locations in Maine									
	Van Buren		Presque Isle		Patten		Old Town		Mean	
	Specific Gravity	Yield per Acre	Specific Gravity	Yield per Acre	Specific Gravity	Yield per Acre	Specific Gravity	Yield per Acre	Specific Gravity	Yield per Acre
Green Mountain	1.077	Bu. 657	1.091	Bu. 565	1.078	603	1.089	Bu. 585	1.084	Bu. 602
Katahdin	1.073	537	1.070	510	1.069	582	1.079	451	1.073	520
Mohawk	1.078	540	1.086	491	1.079	599	1.080	539	1.083	542
Sebago	1.070	502	1.079	471	1.071	533	1.080	503	1.075	502
Kennebec	1.073	664	1.082	593	1.074	821	1.083	619	1.078	674

¹Averages for 10 replications of 25 hills each, except at Old Town, Maine, where there were 8 replications.

The Kennebec appears to be more resistant to net necrosis than Sebago. The keeping quality of the tubers is excellent in the farm storage house at Presque Isle, Maine. From general observation, it appears in this respect to be superior to Sebago and as good as Green Mountain or Mohawk.

It should also be pointed out that the tubers of Kennebec are much more easily detached from the vines than are those of Sebago. This characteristic should be appreciated by growers who have had to pay a premium to get their Sebago potatoes picked.

ADAPTATION AND COMPARISON

Kennebec has been tested for adaptation through the National Potato-Breeding Program. It was included in a group of more than 400 selections, single tubers of which were sent to 20 cooperating state experiment stations for the 1943 crop. A number of the cooperators selected it for further trial. Since that time it has been sent out in larger lots, and the results show that it is widely adapted. The reports vary somewhat, but in general the yields of the new variety are as good as or better than those of the standard varieties for most of the localities in which tests have been made. Its blight resistance is quite outstanding in all locations where this disease is a factor, with the exception of Hawaii where it became rather severely infected with late blight in 1947. This may indicate that different physiologic races of the blight organism are prevalent in Hawaii or that conditions there are especially favorable for the development of the disease.

As has already been shown (tables 3 and 4), Kennebec is very promising as a commercial variety in several sections of Maine besides Aroostook County. Relatively high yields and dry-matter content were obtained in the tests from Bangor northward. In 1946 it ranked first in yield in five tests in different parts of Maine in comparison with Green Mountain, Katahdin, Mohawk, and Sebago, and was first again in 1947 in four tests in comparison with the same four varieties.

It has been rather outstanding in a number of tests in New York State in 1945, 1946, and 1947; so much so that Dr. E. V. Hardenburg of the Division of Horticulture, Cornell University, Ithaca, New York, wrote in his 1947 report: "Seedling B 70-5 gave the highest average yield of any tested in 1947. This is in line with its performance in 1946. It appears to have everything to commend it, including yield, marketability, blight resistance, internal quality, and fairly early maturity."

At State College, Pennsylvania, Kennebec was the highest yielder in a test of 22 varieties. It yielded 472 bushels per acre as compared

with 263 for Rural, 318 for Russet Rural, and 271 for Green Mountain. In the 1947 Rhode Island tests Kennebec showed a relatively large amount of leaf roll but produced 500 bushels per acre as compared with 486 for Green Mountain.

In 1947 at Belle Glade, Florida, Kennebec gave a total of 272 bushels per acre as compared with 212 bushels for Triumph and 219 for Katahdin. It was outyielded by Pontiac with 288 bushels per acre. The report showed a slight amount of late blight and southern bacterial wilt in the Kennebec. In respect to bacterial wilt it showed less infection than Sebago, which was intermediate. Kennebec was given a rating of 1 and Sebago 3, where 0 showed no infection and 5 indicated serious damage with wilt.

At Fort Pierce, Florida, no late blight infection was reported on Kennebec; but there was a moderate amount of early blight infection about 6 weeks after emergence, and this became very severe 15 days later when the plants were 98 per cent defoliated. At the South Carolina Truck Experiment Station, Charleston, South Carolina, Kennebec yielded 453 bushels per acre in comparison with 398 for Irish Cobbler—a significant difference. At Wadmalaw Island, South Carolina, Kennebec yielded 375 bushels per acre as compared with 387 bushels for Irish Cobbler—not a significant difference.

At Shafter, California, Kennebec has outyielded the standard variety White Rose and usually produces a higher percentage of U. S. No. 1 tubers.

From these and other records it is evident that Kennebec is widely adapted.

DISSEMINATION

Several of the State organizations increased Kennebec in 1948, but most of this increase will be sold to foundation seed growers and increased again before it is put on the open market. This is the only way that an adequate supply of seed stock can be produced, since, if the limited amount of seed that is available at present is sold to growers of table stock it would be several years before a worth-while seed supply would be available. Therefore there will be no seed for general distribution until the fall of 1949.

The Department of Agriculture has no seed either for free distribution or for sale. Small lots will be sent out to cooperating State experiment stations for further tests, but none will be available for individual growers.

SUMMARY

The Kennebec is a new variety of potato that combines high yield and good cooking quality with a high degree of resistance to late blight in both vines and tubers. In field-exposure tests it has not yet shown the symptoms of mild mosaic or net necrosis. It is late in maturing as grown in Maine, but has been considered medium-late in tests in other States. It is widely adapted. It produces smooth, well-shaped tubers with shallow eyes. Like all other varieties of potatoes, it varies in quality according to the environment in which it is grown and the cultural practices of the growers. As produced in the test plots on Aroostook Farm, Presque Isle, Maine, it has shown excellent market and cooking quality. The keeping qualities in storage appear to be excellent. Kennebec should replace Katahdin in some sections because of its higher yielding ability, its superior cooking quality, and its high degree of resistance to late blight. It should replace Sebago to a large extent because of a higher degree of resistance to late blight and because the tubers of Kennebec are more easily detached from the vines at harvest time than are those of Sebago.

SUSCEPT RANGE OF THE POTATO RING ROT BACTERIUM

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INTRODUCTION

The following study was undertaken to discover a test plant which, upon inoculation with questionably infected material, would produce rapid, confirming symptoms to indicate presence of the ring rot bacterium. By the end of the limited trials, no better species was found than tomato, a suspect that had previously been suggested for the purpose. Nevertheless, the resultant data are presented at this time for whatever bearing they may have on an allied consideration—the breeding of potatoes for resistance to ring rot. The data may also elucidate the role that additional suspects play in the spread of this disease.

HISTORICAL

The only suspect that is affected by the ring rot organism under ordinary agricultural conditions is the Irish potato. Under conditions, however, of artificial inoculation, the bacterium is capable of causing infec-

tion in a number of other plants. Those which to date have been reported as being susceptible are: *Lycopersicum esculentum* Mill. (Spieckermann and Kotthoff 1914, Stapp 1930, Savile and Racicot 1937, Larson and Walker 1941, *et al.*), *Lycopersicum racemigerum* Lange (Spieckermann and Kotthoff 1914), *Solanum citrullifolium* A. Br. (Spieckermann and Kotthoff 1914), *Solanum commersonii* Dun. (Spieckermann and Kotthoff 1914), *Solanum melongena* L. (Larson 1942, 1944) and *Solanum integrifolium* Poir. (Larson 1943). In addition Stapp (1930) also described the isolation of the ring rot pathogen from artificially inoculated plants of *Pisum arvense* L. and *Phaseolus vulgaris* L., but for these he described the organism as being but "slightly pathogenic." In the case of beans no symptoms were evident, and it is questionable whether the wilting of field peas was actually due to the ring rot organism.

Species which have been inoculated with *Corynebacterium sepedonicum*, but which have been reported as giving no symptoms are recapitulated as follows:

- Antsodus luridus* Link & Otto—(Spieckermann and Kotthoff, 1914)
- Atropa belladonna* L.—(Sp. & Kotth., 1914; Larson, 1944)
- Brassica napus* L.—(Sp. & Kotth., 1914)
- Browallia americana* L.—(Larson, 1944)
- Capsicum annuum* L.—(Sp. & Kotth., 1914; Larson, 1944)
- Datura metel* L.—(Sp. & Kotth., 1914; Larson, 1944)
- Datura meteloides* DC.—(Larson, 1944)
- Datura quercifolia* Godr.—(Sp. & Kotth., 1914)
- Datura stramonium* L.—(Sp. & Kotth., 1914; Larson, 1944)
- Datura tatula* L.—(Sp. & Kotth., 1914)
- Hyoscyamus albus* L.—(Sp. & Kotth., 1914)
- Hyoscyamus niger* L.—(Sp. & Kotth., 1914)
- Lupinus luteus* L.—(Sp. & Kotth., 1914)
- Lycium halimifolium* Mill.—(Larson, 1944)
- Lycopersicum Humboldtii* Dun.—(Sp. & Kotth., 1914)
- Nicandra physaloides* Gaertn.—(Larson, 1944)
- Nicotiana acuminata* Hook.—(Larson, 1944)
- Nicotiana angustifolia* Ruiz and Pav.—(Larson, 1944)
- Nicotiana bigelovii* S. Wats.—(Larson, 1944)
- Nicotiana cerinthoides**—(Sp. & Kotth., 1914)
- Nicotiana chinensis* Fisch.—(Larson, 1944)
- Nicotiana glutinosa* L.—(Larson, 1944)

*Not designated by the author whether this is *N. cerinthoides* Hornem, or *N. cerinthoides* Vitm.

- Nicotiana longiflora* Cav.—(Larson, 1944)
Nicotiana multivalvis Lindl.—(Larson, 1944)
Nicotiana noctiflora Hook.—(Sp. & Kotth., 1914)
Nicotiana quadrivalvis Pursh.—(Larson, 1944)
Nicotiana repanda Willd.—(Larson, 1944)
Nicotiana rustica L. (Sp. & Kotth., 1914; Larson, 1944)
Nicotina rustica L. var. *brasilia* Schrank.—(Larson, 1944)
Nicotiana rustica L. var. *humilis*—(Larson, 1944)
Nicotiana sanderae Hort.—(Sp. & Kotth., 1914; Larson, 1944)
Nicotiana sylvestris Speg. & Comes.—(Larson, 1944)
Nicotiana tabacum L.—(Larson, 1944)
Nierembergia hippomanica Miers.—(Larson, 1944)
Pelargonium zonale L'Herit.—(Stapp, 1930)
Petunia violacea Lindl.—(Larson, 1944)
Physalis Alkekengi L.—(Sp. & Kotth., 1914)
Physalis aequata Jacq. f.—(Larson, 1944)
Physalis heterophylla Nees—(Larson, 1944)
Physalis heterophylla var. *ambigua* (Gray) Rydb.—(Larson, 1944)
Physalis lanceolata Michx.—(Larson, 1944)
Physalis longifolia Nutt.—(Larson, 1944)
Physalis virginiana Mill.—(Larson, 1944)
Salpiglossis sinuata Ruiz & Pav.—(Larson, 1944)
Schizanthus pinnatus Ruiz & Pav.—(Sp. & Kotth., 1914)
Schizanthus wisetonensis Hort.—(Larson, 1944)
Soja hispida Moench.—(Stapp, 1930)
*Solanum balbisii**—(Sp. & Kotth., 1914)
Solanum carolinense L.—(Larson, 1944)
Solanum ciliatum macrocarpum—(Sp. & Kotth., 1914)
Solanum dulcamara L.—(Sp. & Kotth., 1914; Larson, 1944)
Solanum guyanense—(Sp. & Kotth., 1914)
Solanum nigrum L. (Sp. & Kotth., 1914; Larson, 1944)
Solanum pseudocapsicum L.—(Larson, 1944)
Solanum rostratum Dun.—(Larson, 1944)
Solanum spinosissimum Lodd.—(Sp. & Kotth., 1914)
Solanum triflorum Nutt.—(Larson, 1944)
Vicia faba L.—(Stapp, 1930)

*Not indicated by the author whether this is *S. balbisii* Boj. or *S. balbisii* Dun.

PROCEDURE

For this study solanaceous seeds and tubers were solicited from potato breeders and specialists in the Solanaceae, both at home and abroad. **All testing was done on potted plants grown in the greenhouse. In the preliminary runs at least six plants of each species were inoculated and an additional four plants accompanied these as uninoculated checks. In the case of species proving to be susceptible, the number of plants used to test each species ranged from 1 to 36, the number being governed in the lower range by the limitation of available seed.

Plants were inoculated by means of sterilized needles coated with inoculum derived either from pure cultures or from infective ooze of diseased potato tubers, as indicated in table 1. The stab to the vascular region of the main stem was made several centimeters above the ground line, and precautions were taken to prevent over-rapid desiccation of the infection court. Seedlings were inoculated when the diameters of their stems at the point of inoculation were approximately 3 millimeters.

Temperatures over the extended period of testing varied somewhat, an attempt having been made, however, to keep the greenhouse at 24° C. Inoculated tomato plants, grown together with the various test series, indicated by their constant susceptibility that, although temperature variations may have occurred, they were nevertheless within the range permitting infection.

DATA

Data are summarized in table 1. Newly reported susceptibles include 25 species. Reports of 5 previous susceptibles are confirmed. Symptoms are recorded in terms of number and percentage of plants reacting and the range and average of days elapsing to first expression of macroscopic symptoms—usually a chloronemia and wilting of the leaves.

**The following sources are represented, and appreciation is herewith expressed for the generous cooperation received:

- H. A. Senn, Central Experimental Farm, Department of Agriculture, Ottawa, Canada.
- J. G. Hawkes, School of Agriculture, University of Cambridge, Cambridge, England.
- J. P. Sleesman, Ohio Agricultural Experiment Station, Wooster, Ohio.
- F. A. Krantz, Department of Horticulture, University of Minnesota, St. Paul, Minnesota.
- H. N. Racicot, Central Experimental Farm, Department of Agriculture, Ottawa, Canada.
- D. Reddick, Department of Plant Pathology, New York State College of Agriculture, Ithaca, New York.
- W. C. Muenscher, Department of Botany, New York State College of Agriculture, Ithaca, New York.

TABLE 1.—Suscepts of the ring-rot organism, *Corynebacterium sepedonicum* (Spieck. u. Kotth.) Skapt & Burkh.

Suscept	Inoculation with Ooze				Inoculation with Pure Cultures			
	Inoculated Plants		Days to First Symptom		Inoculated Plants		Days to First Symptom	
	Number	Per cent Showing Symptoms	Range	Average	Number	Per cent Showing Symptoms	Range	Average
Newly Reported Suscepts:								
1. <i>Athenaea</i> sp. (BPI 126956)	6	67	40-65	53				
2. <i>Solanum antipodizii</i>	19	68	17-40	33	7	57	28-33	31
3. <i>Solanum ballsii</i>	1	100	16	16	1	100	23	23
4. <i>Solanum chacoense</i>	10	100	19-65	29	4	75	21-28	23
5. <i>Solanum corymbosum</i>	8	100	12-19	14	4	75	12-17	15
6. <i>Solanum demissum</i> <i>atypicum</i>	8	50	19-43	31	3	0	—	—
7. <i>Solanum endlicheri</i>	6	100	19-30	26				
8. <i>Solanum fendleri</i>	9	100	17-42	24	3	100	17-27	20
9. <i>Solanum jujuense</i>	3	67	28-43	36	2	0	—	—
10. <i>Solanum mammosum</i>	8	75	17-60	33	3	100	12-60	33
11. <i>Solanum parodii</i>	13	92	17-51	24	6	83	17-60	24
12. <i>Solanum pampasense</i>					1	100	28	28

TABLE I. (Continued)—Suscepts of the ring-rot organism, *Corynebacterium sepedonicum* (Spieck. u. Koth.) Skapt. & Burkh.

Suscept	Inoculation with Coze			Inoculation with Pure Cultures		
	Inoculated Plants	Days to First Symptom	Average	Inoculated Plants	Days to First Symptom	Average
	Number	Per cent Showing Symptoms	Range	Number	Per cent Showing Symptoms	Range
13. <i>Solanum radicans</i>	12	58	12-19			
14. <i>Solanum tequilense</i>	7	43	17-19	2	100	27
15. <i>Solanum tilarcalense</i>	1	100	27			
16. <i>Solanum vavilovii</i>	9	100	28-40	3	67	28-33
17. <i>Solanum verrucosum</i>	10	100	19-35	4	100	30-45
18. <i>Solanum warszewiczii</i>	6	83	40-65			
19. <i>Solanum</i> sp. (BPI 126461)	6	67	12			
20. <i>Solanum</i> sp. (BPI 127845)	6	50	12-19			
21. <i>Solanum</i> sp. (BPI 127848)	1	100	12			
22. <i>Solanum</i> sp. (BPI 129355)	1	100	12			
23. <i>Solanum</i> sp. (BPI 129381)	7	86	12-30			
24. <i>Solanum</i> sp. (Reddick No. M307)	11	82	13-87	5	100	16-87
25. <i>Solanum</i> sp. (Reddick No. M478)	3	100	12-17	5	100	12-50
						49
						27

TABLE I (Concluded)—Suscepts of the ring-rot organism, *Corynebacterium sepedonicum* (Spieck. u. Koth.) Skapt. & Burk.

Previously Reported Sus- cepts:	6	100	15	15	15	23	100	13-28	17
1. <i>Lycopersicum esculen- tum</i>	6	100	15	12-19	14	5	100	12-42	23
2. <i>Solanum citrullifolium</i>	9	100	17-50	25	16	94	17-50	17-50	26
3. <i>Solanum commersonii</i>	28	100	19-40	26	44	4	100	42-47	43
4. <i>Solanum melongena</i>	6	50	42-47						
5. <i>Solanum tuberosum</i>	3	100							

That symptoms observed were due to the inoculations was checked by comparing affected plants with others of the same species which were not inoculated or were punctured with sterile needles. A further relationship of wilt to infection was established on the basis of stem smears of affected plants. Such smears were made on glass slides from the cut surfaces of stems sectioned radially at a point approximately two centimeters from the site of inoculation. The smears were subsequently stained by the Gram technique and were examined for the presence of bacteria resembling, in their staining reaction, size, morphology, and grouping, the ring rot bacterium.

Those species of solanaceous plants which showed no susceptibility to the ring-rot organism during the course of this study are as follows:

- Atropa belladonna* L.
- Capsicum annuum* L.
- Nicotiana tabacum* L.
- Physalis angulata* Heyne
- Saracha procumbens* Math. ex Dun. & A. DC.
- Solanum acaule* Bitter
- Solanum acaule* var. *subexinterruptum**
- Solanum aculeatissimum* Jacq.
- Solanum antigenum* f. *hederisegmentatum**
- Solanum demissum* Lindl.
- Solanum demissum atrocyaneum**
- Solanum demissum* f. *tlaxpehualcoense**
- Solanum dulcamara* L.
- Solanum gilo* Requier
- Solanum guineense***
- Solanum indicum* Roxb.
- Solanum neoantipoviczii* var. *Reddickii* Bukasov
- Solanum nigrum* var. *pumila**
- Solanum pyracanthum* Jacq.
- Solanum tripartitum* Dun.
- Solanum* sp. (Reddick Acq. No. 1072)
- Solanum* sp. (BPI 123831)
- Solanum* sp. (BPI 126458)
- Solanum* sp. (BPI 126465)
- Solanum* sp. (BPI 126965)
- Solanum* sp. (BPI 127841)
- Solanum* sp. (BPI 127843)

*Authority not determinable.

**Not indicated whether this is *S. guineense* Lam. or *S. guineense* L.

Solanum sp. (BPI 127844)

Solanum sp. (BPI 127849)

Solanum sp. (BPI 129352)

In addition to the non-susceptible solanaceous species listed above, various crop plants were inoculated as previously described. The ooze from a number of potato tubers in an early stage of ring-rot infection was used as inoculum, and 12 plants of each variety were inoculated. None of the following showed above-ground macroscopic symptoms of infection even for 60 days following inoculation:

Apium graveolens L. (Celery, var. Salt Lake)

Beta vulgaris L. (Beet, var. Detroit Dark Red)

Brassica oleracea L. var. *acephala* DC. (Kale, var. Dwarf Green Curled)

Brassica oleracea L. var. *botrytis* L. (Cauliflower, var. Burpeeana)

Brassica oleracea L. var. *capitata* L. (Cabbage, var. Early Jersey Wakefield)

Brassica rapa L. (Turnip, var. Purple Top White Globe)

Cuscuta sp. (Tourn.) L. (Dodder)

Daucus carota L. (Carrot, var. Chanteney)

Helianthus sp. L. (Sunflower)

Lactuca sativa L. (Lettuce, var. Big Boston)

Phaseolus vulgaris L. (Bean, var. Pencil Pod Black Wax)

Pisum sativum L. (Pea, var. Little Gem)

Soja Max Piper (Soybean)

Spinacia oleracea Mill. (Spinach, var. Giant Thick-leaved)

Trifolium pratense L. (Red Clover)

DISCUSSION

It should be pointed out that *Solanum demissum* occurs in the list of ring-rot susceptibles as well as in the list of non-suscepts, differing only in that the former listing designates the *demissum* as *Solanum demissum atypicum*. Eleven plants of *S. demissum atypicum* were inoculated at various times over a period of two and a half years and of these, four showed external symptoms of ring-rot infection. Gram-stained smears of the affected stems were also prepared, and these showed the presence of *Corynebacterium sepedonicum*. On the other hand, 5 other collections of *S. demissum*, designated *S. demissum* f. *tlaxpehualcoense*; *S. demissum*, El desierto; *S. demissum*, Rio Janeiro; *S. demissum atrocyanum*, El desierto; and *S. demissum Xitlense*, El desierto were tested, and of the 28 inoculated plants comprising this group, none showed any evidence of susceptibility. In conversation with Dr. Donald Reddick, who

annexed the appellation "*atypicum*" to the species *S. demissum*, the writer was informed that this variant differed from the typical *S. demissum* in that its foliage was of a little deeper green, that its leaflets in proportion were a little broader, also that the terminal leaflet formed a better ellipse, but that the hump was somewhat distal of center, and that the berry was a little paler than normal. A difference was also noted in the immunity of these two strains: the typical *demissum*, in the course of extensive testing by Dr. Reddick for late blight susceptibility, has repeatedly reacted as immune; the strain *atypicum*, on the other hand, has consistently shown a susceptibility to blight. This discrepancy between the two strains as to late blight as well as to ring-rot susceptibility, may have its explanation in a heterozygosity of resistance factors in the *atypicum* variant—a possibility suggested by its differing phenotypic, vegetative, and fruiting characteristics. To determine whether *Solanum demissum atypicum* differs from other *S. demissum* forms in its susceptibility to ring rot, or whether the species as a whole is but highly resistant, will require further investigation.

Especial attention has been called to *Solanum demissum* and its forms since that species has shown immunity to the important potato late blight disease, and has, therefore, been used by Reddick (1943) in breeding commercial potatoes resistant to the disease. Resistance or immunity of *S. demissum* to ring rot might conceivably be an additional factor in favor of its use as parentage material in a potato breeding program.

SUMMARY

Twenty-five new susceptibles of the potato ring rot organism, *Corynebacterium sepedonicum* (Spieckermann and Kotthoff) Skapt. and Burkh., are given. An additional 45 species are listed as showing no reaction to the disease. The differences in susceptibility between *Solanum demissum* and *S. demissum atypicum* are emphasized.

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THE EFFECT OF CHEMICAL VINE KILLERS ON YIELD AND QUALITY OF RED McCLURE AND BLISS TRIUMPH POTATOES

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Potato vine killers have come into vogue in Colorado during the last two years for the purpose of lengthening the harvest period and toughening the tuber skins to reduce scuffing and mechanical abrasion. Little was known about the effect of these chemicals on the tubers and since contradictory reports were being voiced it seemed that some factual evidence was needed. This was especially true for the San Luis Valley where bright red tubers bring a price differential on the market and where the maintaining of high cooking quality is a major consideration.

In 1946 and 1947 experiments were conducted at the Colorado Potato Station, Greeley, and at the San Luis Valley Branch Station²—to determine which vine killers were effective on potatoes grown under irrigation in the semi-arid west and what the effects were on the tubers.

Randomized block designs were used both years. In 1946 four replications were used at both places and in 1947 five replications were used at the Colorado Potato Station and six at the San Luis Valley Branch Station. All sprays were applied with a wheelbarrow sprayer at the rate of 100 gallons per acre about two weeks prior to a killing

¹Horticulturist, U. S. D. A. Bureau of Plant Industry, Soils, and Agricultural Engineering.

²The writers wish to thank W. F. McGee, Supt. of the San Luis Valley Branch Station for his assistance in these investigations.

frost. One exception was at the San Luis Valley Branch Station in 1946 when a power sprayer was used to apply the chemicals.

Color measurements were made with the disc colorimeter as described by Sparks² and specific gravity was computed from the relationship: weight of the dry tubers in air divided by the difference between the weight of the tubers in air and the weight of the tubers when immersed in water. The data for stem end discoloration was not taken until about 75 days after harvest during which time the tubers were stored at approximately 40° to 50° F. in 1946. In 1947 the Triumph tubers were stored at about 40° to 60° F. and the Red McClure potatoes at room temperature. It was hoped that by waiting 75 days any discoloration that was to develop would appear. Determinations were made on samples of approximately 50 tubers from each plot.

RESULTS

Table 1 gives the chemicals and the concentrations used at the Colorado Potato Station in 1946 and 1947, the relative speed of kill and the percentage of stem end discoloration. The effect of the chemicals on yield, grade, color and specific gravity was determined; but since none of the differences except in the case of specific gravity and stem

TABLE 1.—*Potato vine killer and the concentrations used, arranged according to the rate of kill on Triumph potatoes at the Colorado Potato Station, Greeley, Colorado, in 1946-1947*

Vine Killer	Concentration Used	Rate of Kill ¹	Percentage Stem End 1946	Discoloration 1947
Sodium Nitrite	100 lbs./100 gal. water	1	13.2	—
Dowspray 66	1 gal./100 gal. water + 2 lbs. aluminum sulfate	1	—	12.8
Dowspray 66	1 gal./100 gal. water + 10 lbs. copper sulfate	1	—	12.1
Dowspray 66	1 gal./100 gal. water	2	14.1	10.6
Sinox	2 gal./100 gal. water + 10 lbs. ammonium sulfate	2	13.5	—
Ammonium sulfate	200 lbs./100 gal. water	4	—	8.1
Hammond's weed killer	2½ gal./100 gal. water	6	—	7.7
Sodium nitrite	50 lbs./100 gal. water	6	10.4	9.9
Check			19.2	13.1

¹The smaller the number the quicker the kill, but a rating of 1 is not to be construed to mean the kill was twice as fast as a rating of 2, nor 6 times as fast as a rating of 6.

end browning approached significance they are not included in the table. In 1946 there was almost significantly more stem end discoloration in the tubers from the untreated check than in those from vines which had been killed with a vine killer as shown in table 1. In 1947 the vine killers were applied only two days before a frost which killed 50 per cent of the foliage and consequently no significant differences were found.

The effect of potato vine killers on Red McClure potatoes in 1946 is shown in table 2. The vine killers were applied seventeen days before

TABLE 2.—*The effect of Dowspray 66 and Sinox on the color, specific gravity, and percentage of stem discoloration of Red McClure potatoes when applied 17 days ahead of the first killing frost in 1946.*

Vine Killer	Concentration Used	Per cent Stem End Discoloration	Per cent Eugenia Red Color	Specific Gravity
Sinox	1 gal./100 gal. water + 10 lbs. ammonium sulfate	19.4	72.1 ¹	1.0796
Dowspray 66	1 gal./100 gal. water	18.9	71.9	1.0822
Check		8.9*	76.2*	1.0874*
M.S.D.				
1 Per cent		13.2	4.89	.0064
M.S.D.				
5 Per cent		8.7	3.23	.0042

¹The color rating indicates the percentage of the Eugenia red component, the remainder being light pinkish cinnamon (Ridgeway's Color Standard).

frost killed the vines on the check plots and the tubers were dug two days later.

From the data in table 2 it can be seen that there was no difference between the effect of Sinox and Dowspray 66 insofar as stem end discoloration, color of tuber or specific gravity are concerned. However, tubers from the vine-killed plots showed markedly more stem end discoloration, significantly less color, and a much lower specific gravity than the tubers from the check plots which had been permitted to grow about sixteen days longer.

In the 1947 experiment at the San Luis Valley Branch Station two sets of check plots were included. One was harvested the day following the application of the vine killers to determine the status of the tubers at the beginning of the experiment. The other served as the untreated check. Fourteen days after the vine killers were applied, and while the

vines on the untreated check were still green, a killing frost, which killed the vines to the ground, occurred. Two days later, on the 16th of September, the plots were dug. The results are shown in table 3.

Table 3 indicates that the vine killers were not equally effective in producing a rapid kill. Of the materials used Sinox and Dowspray 66 alone and in combination with other materials gave the quickest kill. No significant "F" value was found by analysis of variance for stem end discoloration when comparing the treatments listed in table 3. Tuber color was at its best at the time the vine killers were applied. Specific gravity of the tubers was the highest where the vines lived the longest. There was also some indication, at odds of nearly 19:1 that the specific gravity was not so good in those tubers where the vines have been killed by a vine killer and the tubers left in the soil for sixteen days, as in those tubers harvested at the beginning of the experiment.

There was so much variation within treatments that it was not possible to determine the amount of increase in yield obtained by letting the plants live two weeks longer. Nevertheless the tubers were graded into three sizes: below 1½ inches in diameter, 1½ inches to 2 inches, and over 2 inches.

It was found, in table 3, that digging the tubers two weeks ahead of the frost increased the amount of tubers under two inches in diameter by 5.7 per cent by weight, at odds greater than 99:1. Killing the vines with a vine killer did not cause significantly more tubers under two inches in diameter than occurred in the untreated check which was harvested on the 16th of September. The difference in total yield was not significant, because of the large variation within treatments.

DISCUSSION

In some preliminary work with potato vine killers in the greenhouse it was found that Dowspray 66 when combined with copper sulfate at the rate of ten pounds per 100 gallons of spray would kill late blight spores¹ whereas Dowspray 66 alone or in combination with aluminum sulfate did not. Copper sulfate is more expensive than aluminum sulfate but the added cost may be more than off-set by the fungicidal effects in late blight areas should it prove effective against late blight in the field.

Stem end discoloration has been a major concern and no doubt has limited the use of vine killers to some extent. However, at this

¹Determinations made by Dr. W. D. Thomas of the Botany Department of Colorado A. & M. College.

TABLE 3.—*The effect of various potato vine killers on the per cent grade, color, stem-end discoloration, and specific gravity when applied to Red McClure potatoes two weeks ahead of the first killing frost*

Vine Killer	Concentration Used	Rate of Kill	Pct. Stem-end Discoloration	Pct. Eugenia Red Color*	Specific Gravity	Tubers 2" in Diameter
Dowspray 66	2 gal./100 gal. water + 2 lbs. aluminum sulfate	1	11.4	65.5	1.0834	94.1
Dowspray 66	2 gal./100 gal. water + 10 lbs. copper sulfate	1	7.7	64.2	1.0831	94.7
Dowspray 66	1 gal./100 gal. water + 2 lbs. aluminum sulfate	2	11.0	65.5	1.0843	94.0
Dowspray 66	1 gal./100 gal. water + 10 lbs. copper sulfate	2	9.8	64.3	1.0827	94.0
Sinox	2 gal./100 gal. water + 10 lbs. ammonium sulfate	2	10.3	63.4	1.0821	93.7
Ammonium sulfate	200 lbs./100 gal. water	5	10.2	63.5	1.0839	94.2
Sodium nitrite	50 lbs./100 gal. water	6	13.1	65.3	1.0858	93.7
Hammond's weed killer	2½ gal./100 gal. water	8	8.9	64.4	1.0851	93.9
Fairmont weed killer	2½ gal./100 gal. water	8	8.2	64.8	1.0833	94.6
Check	Dug September 2, 1947	—	—	68.1	1.0859	88.8
Check	Dug September 16, 1947	—	9.5	64.9	1.0873	94.5
M.S.D. 5 Pct.			N. S.	2.26	0.0027	1.19
M.S.D. 1 Pct.				3.02	0.0036	1.59

*The color rating percentage of the Eugenia red component, the remainder being light pinkish cinnamon (Ridgeway's Color Standards).

time it seems doubtful that any additional discoloration was caused by their use. Photographs made of the various types of stem-end discoloration in 1946 show it is quite possible that some of the discoloration was due to net necrosis and probably not to the vine killers used. In 1947 it was found that stem-end discoloration could be distinguished from net necrosis by the use of ultraviolet light, consequently in 1947 tubers listed under stem-end discoloration are those that were discolored but did not show fluorescence when cut about one-fourth of an inch from the stem end.

Of the vine killers tested under Colorado conditions it appears that only those worthy of consideration are Dowspray 66, alone or in combination with aluminum or copper sulfate, and Sinox. Sodium nitrite at high concentration proved to be an effective vine killer, but its use is not recommended because of the already high sodium content of the soils.

SUMMARY

Chemical potato vine killers were tested at The Colorado Potato Station on Bliss Triumph potatoes and at the San Luis Valley Branch Station on Red McClure potatoes in 1946 and 1947. In 1946 at the Colorado Potato Station there was almost significantly more stem-end discoloration in tubers from the untreated check than in those from the treated plots. At the San Luis Valley Branch Station the same year there was significantly more stem-end discoloration in the tubers from the chemically treated plots than in those from the untreated check.

The 1947 results at the Colorado Potato Station were inconclusive due to a killing frost just two days after the chemical vine killers were applied. The results at the San Luis Valley Branch Station in 1947 indicate: (1) that when the tubers were harvested, about two weeks before harvesting the untreated check, a significant decrease in yield of tubers more than two inches in diameter resulted; (2) that killing the vines prematurely resulted in a lower specific gravity; and (3) that tuber color faded with maturity. Killing the vines with a vine killer about two weeks ahead of the first killing frost did not decrease the amount of tubers which were more than two inches in diameter. None of the vine killers used in 1947 caused a significant increase in the amount of stem-end discoloration.

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SOIL FERTILITY INVESTIGATIONS WITH POTATOES
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Although larger quantities of fertilizer had been used for potatoes in Northern Wisconsin than for most other crops in the state, in many cases yields have not been satisfactory. During the course of the investigation reported here, which was started in 1942, nutritional disorders of potatoes involving manganese toxicity, magnesium deficiency, potassium deficiency and nutrient unbalance have appeared in the field. These nutritional disorders, in many cases, were the limiting factors in the yields of potatoes. In the past, growers have used, within narrow limits, the same amounts of plant food irrespective of soil fertility status. A reluctance to use lime, because of the danger of scab infestation, has led to excess soil acidity and magnesium deficiency in some cases. The use of the same amounts of plant foods on all soils has led to nutrient unbalance.

In order to determine why lower yields were becoming more common in Northern Wisconsin, greenhouse, laboratory, and field experiments were started in 1942 and the results are reported here.

PROCEDURES

In all field experiments four replications of each treatment were made in a randomized block arrangement. Individual plots were four rows wide and 60' long. Fertilizer applied in the row was applied in bands with commercial potato planters. Fertilizers applied broadcast were usually weighed out for each plot and applied by hand or they were applied with the fertilizer broadcaster which had been previously calibrated. The amount of fertilizer actually applied to each plot was determined by adding a known amount to the machine and weighing the fertilizer remaining in the hopper after application. Fertilizer was usually applied to the soil after plowing and was double disced so as to mix it directly with the top 3-5" of soil.

Lime was applied in a manner similar to fertilizer. In all cases finely ground dolomitic limestone was used. This material contains approxi-

¹Contribution from the Department of Soils, University of Wisconsin, Madison 6, Wis. Published with the permission of the director of the Wisconsin Agricultural Experiment Station.

²Associate Professor in Soils.

mately 41 per cent magnesium carbonate and 47 per cent calcium carbonate. It is ground so that about 97 per cent passes a 100-mesh screen and 72 per cent passes a 300-mesh screen.

For harvest, five feet was hand dug and discarded from the end of each plot and the center two rows 50 feet long taken for yield. The tubers were weighed in the field and yields calculated to an acre basis.

Available phosphorus and potassium determinations were made by the Truog quick test procedure. Available calcium and magnesium were determined by displacement with normal, neutral, ammonium acetate solutions and subsequent precipitation and titration. The pH of these soils was determined in part colorimetrically and in part with a glass electrode.

CHEMICAL COMPOSITION OF SOILS

Preliminary investigations indicated that the potato soils, after 10 to 30 years of cultivation contained high amounts of available phosphorus, were low in available potassium, and were very strongly acid. During this investigation, numerous samples were collected from virgin soils and from soils where potatoes had been grown for a number of years. These samples were analyzed for available phosphorus, potassium, calcium, and magnesium, and the pH of these soils was determined. These data are given in table 1. Although virgin samples could not always be taken near cultivated fields, it is felt that the results given are representative of the nutrient status of the soils in northern Wisconsin.

As can be seen in table 1, 10 to 30 years of cropping to potatoes has resulted in an increase in acidity from medium acid in the virgin soils to very strong acidity in the cultivated soils. The available phosphorus content of the cultivated soils is from two to four times that of the virgin soils. The available potassium content of the cultivated soils has decreased so it is now about one-half to three-fourths that of the virgin soil, the available calcium content is about 60 per cent of that of the virgin soils, and the available magnesium content ranges from about one-third to one-half as much in the cultivated as in the virgin soils. This increase in available phosphorus and decrease in available potassium, calcium, and magnesium show that fertilizers on these soils have not been properly balanced.

Common applications of fertilizer in the past have been 800 pounds to the acre of such analyses as 4-8-8, 3-12-12, and in rare instances, 3-9-18 applied in bands at side of the seed in the row Hawkins *et al.* (3)

TABLE I.—*Chemical composition of virgin and cultivated northern Wisconsin potato soils.*

Soil Type	Number of Samples	pH	Pounds per Acre Available			
			P	K	Ca	Mg
Virgin Soils						
Vilas sandy loam	5	5.3	68	168	887	116
Onamia loam	6	5.3	65	124	985	121
Omega sand	9	5.5	35	120	685	97
Antigo silt loam	7	5.4	44	135	960	127
Cultivated Soils						
Vilas sandy loam	12	4.6	124	85	529	63
Onamia loam	27	4.4	127	85	578	57
Omega sand	15	4.6	131	71	375	35
Antigo silt loam	25	4.5	126	93	670	58

(4)³ have shown that a good yield of potatoes will contain in the tops and tubers 40 pounds of nitrogen (N), 30 pounds of phosphoric acid (P_2O_5) and 250 pounds of potash (K_2O). It is obvious that because the potato crop uses a low amount of phosphorus and a high amount of potash, and because the fertilizers applied did not contain a somewhat similar ratio of phosphorus to potassium, the phosphorus content of the cultivated potato soils has increased although the potassium content had decreased.

The results show that for best growth and yields of potatoes these soils are now too low in available calcium, magnesium and potassium.

FERTILIZER EXPERIMENTS

The rotation used by most of the certified seed growers in northern Wisconsin consists of oats seeded to red clover, red clover, and potatoes. The oats is combined, all the straw is left on the field the first year. The second year red clover is combined for seed but no hay is removed and in the fall it is usually worked for weed control and in so doing the clover is thoroughly chopped up and incorporated into the soil. The land is plowed the following spring and potatoes planted. This is a very good rotation and one which supplies a considerable amount of nitrogen as well as other plant foods for the potato crop. Most of the fertilizer experiments reported here were with potatoes in such a rotation.

Because of rather low summer rainfall with relatively poor distribution during July and August in Wisconsin, the application of more

³Figures in parenthesis refer to "Literature Cited."

than 800 pounds per acre of the fertilizer in the row is usually not beneficial to potatoes. Therefore, it was decided early in this investigation that because larger amounts of fertilizer were obviously necessary for potatoes, it was best to apply them broadcast. Several experiments conducted with more than 800 pounds of fertilizer in the row have confirmed this observation. Various ratios of nitrogen, phosphoric acid and potash were applied broadcast and the results obtained with these various ratios are given in table 2. Numerous other ratios were tried and discarded after one or two ears' trial because of obvious poor results.

TABLE 2.—*Yields of potatoes as influenced by various mixtures of complete fertilizers applied broadcast in addition to the application of 800 pounds of 3-12-12 applied in the row. Average of experiments on five fields during three years.*

Fertilizer Application						Acre Yield Bushels
Check, no fertilizer						136
Fertilizer in row, none broadcast						180
"	"	"	plus 1200 lbs. 6-6-18	broadcast		270
"	"	"	"	1200 lbs. 6-3-18	"	257
"	"	"	"	1200 lbs. 6-6-27	"	243
"	"	"	"	1200 lbs. 6-6-9	"	239
"	"	"	"	1200 lbs. 12-6-18	"	236

The data show, that although there was a large increase in yield with the application of 800 pounds of 3-12-12 in the row, additional applications of 1200 pounds of a high potash fertilizer gave much greater increases in yield. It was found that the best analysis fertilizer to apply broadcast was a 6-6-18 fertilizer. As shown in table 2, although the average yields were increased 44 bushels by the application of fertilizer in the row, the broadcast application of 1200 pounds of 6-6-18 in addition to the row fertilizer gave a further increase in yields of 90 bushels per acre. This fertilizer ratio gave better results than did higher or lower potash, nitrogen, or phosphate, on the average. The highest experimental yields, however, was obtained with a 6-3-30 fertilizer in 1942, a year of good rainfall. Field appearance of the potatoes with this treatment are shown in figure 1. The plot shown yielded 606 bushels per acre but in other years of less favorable distribution of rainfall, the yields with this treatment were much lower than with 6-6-8 fertilizer.



FIG. 1. Fertilizer experiment with Triumph potatoes on Omega sand, 1942.
Dark colored plot between two men received 700 pounds of 3-12-12 side seed plus 1200 pounds of 6-3-30 broadcast. Yield of plot 606 bushels per acre.
Right of men—700 pounds 3-12-12 side seed, yield 410 bushels per acre.

In table 3 yields are given, comparing results obtained in various years with no fertilizer, row only, and row plus 6-6-18 applied broadcast. As can be seen, the yields are quite variable, depending on weather and soil conditions. In every year, however, the broadcast application of fertilizer resulted in an increase of yield over the row fertilization. Because most of the potato soils now contain high phosphorus and low potassium, it is felt that this fertilizer treatment will probably give the best results on the majority of the soils. There are, however, a few soils that are relatively high in available potassium, and with these soils, the broadcast application of fertilizer will not always be profitable, especially where large crops of clover are grown and turned under to supply the nitrogen needed.

LIME EXPERIMENTS

As previously shown, the potato soils in northern Wisconsin are now too acid for best growth of potatoes due partially to excess manganese present in these soils but also to a lack of calcium and especially

TABLE 3.—*Yields of potatoes with no fertilizer, row application only, and row plus broadcast applications on different soil types. Results from nine fields over six-year period.*

Soil Type	Year	Acre Yield in Bushels		
		No Fertilizer	800 Lbs. 3-12-12 in Row	800 Lbs. 3-12-12 in Row Plus 1000 to 1200 Lbs. 6-6-18 Broadcast
Omega sandy loam	1945	90	148	220
Omega sandy loam	1943	119	127	174
Antigo silt loam	1946	188	299	319
Omega sand	1947	191	204	280
Antigo silt loam	1945	199	265	426
Omega sandy loam	1944	254	282	297
Antigo silt loam	1944	260	296	354
Omega sand	1942	268	409	563
Onamia sandy loam	1947	320	390	474
Average		209	269	345

magnesium. In 1946, magnesium deficiency symptoms were found for the first time in Wisconsin. These were found in northern Wisconsin on potatoes. The apparent inefficiency of potatoes in the absorption of phosphorus from the soil might probably be due to a lack of magnesium in the soil. It has been shown (5) that when the magnesium content of the soil was low, the phosphorus content of pea seed could be increased by increasing the supplies of available magnesium. It is quite possible that the same mechanism works with potatoes.

Before this work was started in Northern Wisconsin it had been noted that on some soils there appeared a severe stem streak necrosis of potatoes which caused early death of the plant and subsequent reduced yields. During this investigation it was found that the stem streak necrosis occurred more often on soils more acid than pH 5.1 and that it was caused by excess manganese in the soil solution. The high acidity brought about conditions which were favorable for the change of the rather insoluble manganese dioxide to the highly soluble manganous manganese. It was also shown that the excess amounts of manganese in the soil solution could be removed by the application of small amounts of finely ground limestone. This work has been reported in detail elsewhere (1) (2).

Because of these three factors, low calcium and magnesium and excess manganese, not only has the potato crop been affected adversely but in many cases it has not been possible to grow a green manure clover

crop. Lime has not been applied more generally because of a fear of scab. Results given in table 4 show that the application of lime directly

TABLE 4.—*Yields of potatoes as influenced by the application of lime at the rate of 300 to 1000 pounds per acre with various fertilizer treatments. Average of five fields during four years.*

Fertilizer Application	Acre Yield, Bushels		
	Unlimed	Limeed	Increase Due to Liming
None	180	194	14
800 lbs. 3-12-12 in row	241	265	24
800 lbs. 3-12-12 in row plus 1200 lbs. high potash fertilizer broad- cast	281	314	33

to potatoes increases the yield on the average from 14 to 30 bushels per acre. Because of this, the application of 300 to 1000 pounds of finely ground limestone is recommended on potato soils more acid than pH 5.0. Furthermore preliminary experiments with various fertilizer materials have shown that in some cases yields have been appreciably increased by the addition of soluble magnesium, as sulfate of potash-magnesia, in the fertilizer applied. Because the magnesium content of these soils are so low and because only a small amount of dolomitic limestone can be added the application of soluble magnesium in the fertilizer is recommended.

SODIUM EXPERIMENTS

Because of the possibilities of potassium supplies being short during the war, a series of sodium experiments with potatoes were initiated in 1943. Results in figure 2 show that the dry weights of potatoes, tops and roots could be increased with the addition of sodium to the nutrient solution when potatoes are grown in water culture and that sodium could be used to replace a part of the potassium. In figure 3 the growth of potatoes is shown with and without sodium at six levels of potassium. The data indicate that a small amount of potassium can be replaced with sodium. Although conclusive results were obtained in the greenhouse, results obtained in the field were erratic and incomplete and at the present, field experiments to determine the rôle of salt in the nutrition of potatoes are still in progress.



FIG. 2. Growth of Triumph potatoes in water culture with two levels of potassium and with and without additions of sodium.

A—No potassium, no sodium added.

B—No potassium, 125 parts per million sodium added.

C—168 parts per million potassium, no sodium added.

D—168 parts per million potassium, 25 parts per million sodium added.

SUMMARY

Analyses of virgin and cultivated Northern Wisconsin soils show that when potatoes are grown on these soils for from 10 to 30 years the available phosphorus and soluble manganese content and acidity are increased while the available potassium, calcium, and magnesium contents are seriously depleted.

Field experiments have demonstrated that for broadcast application a 6-6-18 fertilizer has given higher yields, at 1200 pounds per acre, than have analyses with higher or lower nitrogen, phosphate or potash. These fertilizers were all applied with a uniform application of 3-12-12 in the row. Applications of more than 800 pounds per acre of fertilizer in the row were not beneficial. An average of experiments on nine fields in seven years shows that the application of 800 pounds of 3-12-12 in the row increased the yield, over the unfertilized, about 60 bushels per acre. The additional application of 1200 pounds of 6-6-18 gave a further increase of 80 bushels.

Field, greenhouse, and laboratory tests show that when soils are

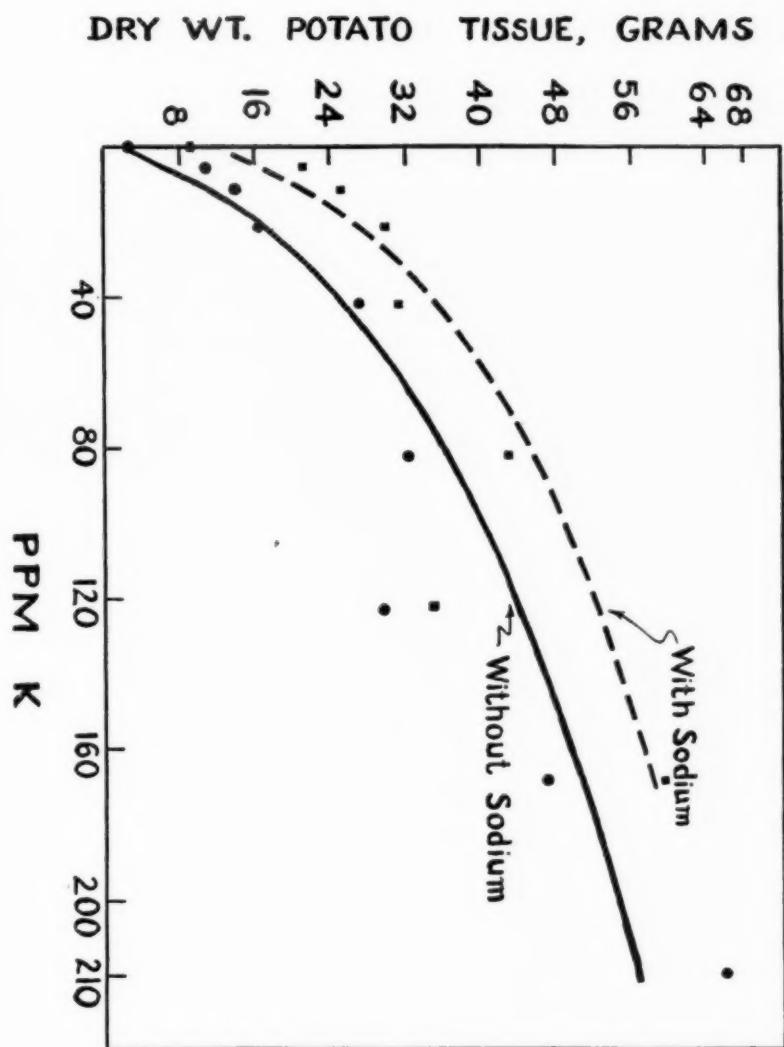


FIG. 3. Influence of sodium on dry weight of potato tops and roots produced in water culture. The amount of sodium added varied with the potassium present so that the total sodium and potassium was always equivalent to 210 p.p.m. of potassium.

below pH 5.0, finely ground dolomitic limestone should be applied to add available calcium and magnesium to the soil, and to reduce the excess amounts of soluble manganese present in some of these soils. It is often advisable to add some soluble magnesium in the fertilizer, in addition. Manganese toxicity, known as stem streak necrosis of potatoes, and magnesium deficiency are quite common on these soils.

In greenhouse experiments it was demonstrated that the addition of sodium to the nutrient solution, in which potatoes were grown, increased the dry weight of tops and roots when the potassium content of the solution varied from none to 210 parts per million. Consistent increases in yields were not obtained in the field, however.

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SECTIONAL NOTES

MICHIGAN

The crop that is being harvested is in fine shape. The weather has been very favorable. Our yields, generally speaking, are above normal; and in some areas we have the highest yields we have ever harvested.

Our greatest problem is storage. Since the Michigan acreage was shifted to different areas of production, the storages in some areas are not being used. The new producing areas are short on storage, which makes it necessary to ship a considerable quantity of their stocks out before cold weather.

Our shipments to the government, at present, far exceed those shipments to the trade. Government shipments are used chiefly for alcohol and flour. It is generally thought that the government estimate on Michigan's crop is low.

It is too early to give any definite information on the Certified Seed situation, as our final inspection has not yet been completed.—H. A. REILEY.

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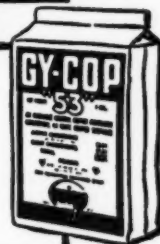
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NEW JERSEY

The New Jersey potato crop is now harvested and despite the excessive rainfall in the spring, our yields have averaged higher than in any previous year. The U.S.D.A., in its October report, estimates the yield at 221 bushels per acre which is a 48 bushel increase above the average yield for the ten-year period 1937-1946. The quality of our potatoes has been very good but unfortunately many of these good potatoes have been converted into flour through the government price support program, leaving the commercial grade to be sold to the consuming public. This fact has led many consumers to think that New Jersey potatoes were inferior in quality.

Most of our growers believe that there must be a reduction in potato acreage throughout the country and perhaps the government plan to cut price support to 60 per cent of parity, is one method to accomplish this, but they definitely do not plan to cut their acreage by 33 per cent, as was recently suggested by the government. Such a large cut is unfair to any area that has complied with government regulations as closely as have the New Jersey growers, whereas other areas that have planted approximately twice their allotted acreage are given a smaller cut. Some of our growers feel that a price support of 60 per cent of parity would remove the ill feeling about price support current among some people, but they also believe that a new parity figure should be established taking into account the average yields per acre in the various areas.—J. C. CAMPBELL.

NEW YORK

Potato harvest is in full swing with the largest average yield per acre ever reported. Because of the long growing season ending with dry weather, our quality is excellent.

Except in concentrated areas, growers are not utilizing the government program to move potatoes. Every storage will be filled to capacity and a lot of low grades will be utilized for cattle feed.

Reports of recent years where potatoes have been fed to cattle indicated excellent returns. The standard recommendation is to feed potatoes as a supplement rather than a substitute for any other feed. Cows appreciate the variety and respond accordingly.

The few processing plants we have in New York State are operating to capacity.

The Seed Potato crop, for the most part, is good. Seed growers have planted very close to keep size down and many growers have killed vines with chemicals, flame and roto-beaters. Virus diseases were lower

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this season than has been the case for many years, and a relatively small percentage of the acreage will be turned down. With both good size and quality our seed growers are not anxious to move seed until spring.

The attitude of up-state potato growers generally in regard to the proposed 1949 Program is favorable. The proposed reduction in acreage is rather drastic on Long Island and there will be some objection to the cut there but many Long Islanders have expressed the thought that they might get more money with considerably less acreage.—H. J. EVANS.

NORTH DAKOTA

North Dakota potato growers have just harvested the best crop of certified seed potatoes they've ever had and that's some record, for this state always ranks at the top in the production of seed potatoes. The quality is exceptional and the yield much greater than anticipated.

Ideal weather conditions both during the growing season and harvest contributed immensely toward making this a banner year in North Dakota's seed potato history. Dry, cool days over long periods developed the seed gradually to its maturity. The potatoes, when harvested, were bright, clean and smooth. More than 90 per cent of North Dakota seed potatoes are dry-land grown above the 47th parallel north which accounts for their unusual vigor.

One hundred of the certified seed potatoes are harvested now, according to R. C. Hastings, state seed commissioner. Ten per cent have already been marketed. The balance has been put in storage ready for future deliveries. The most popular varieties grown in North Dakota are Bliss Triumphs, Irish Cobblers, Red Pontiacs, Pontiacs, Red Warba, White Rose and Early Ohio. There are also some small acreages in various other new varieties, which have been planted for experimental purposes.—GRACE HUDSON.

PROVINCE OF ONTARIO

Harvesting of the potato crop is now in full swing with conditions ideal. The quality of this year's crop in Ontario is exceptionally good. Although our tubers are somewhat larger than usual, there will be little loss from blight. There is a noticeable decrease this year in the amount of surface scab found in commercial areas, and in most cases, the tubers are well matured, with a smooth, clean, and attractive appearance.

Growers have substantially increased their mechanical equipment and a large number have acquired tractor driven power-take-off harvesting outfits, with picker attachments and in some cases, graders and load-

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ers. They are preparing to supply a larger quantity of potatoes that are annually imported for consuming purposes in the Province.

Although the present prices to growers cannot be considered high, there is recently an increasingly firmer tone to the market. Growers, with poor quality potatoes and with low yields per acre, are finding that present prices do not pay production costs, and also that demands for potatoes which do not meet requirements of Canada No. 1 grade are very limited. Considering excellent outlets for meat and milk products, it is likely that large quantities of cull and off-grade potatoes will be utilized to good advantage on farms as livestock feed.

The present quotations on Toronto market are lower than any other large consuming center in the Province, and on the 7th of October were \$1.25 to \$1.35 per 75-lb. bag for a Canada No. 1 grade on a wholesale to retail basis. Arrivals from P.E.I. and N.B. this season to date have been practically *nil*. With our present and anticipated outlets for large quantities of Maritime stocks to U.S.A. and other export markets, together with the fact that price differential favors the purchase of Ontario potatoes, consumers are showing preference for the high quality local product, during these times of increased living costs for many commodities with the exception of potatoes.—R. E. GOODIN.

PROVINCE OF PRINCE EDWARD ISLAND

Our potato crop this year in Prince Edward Island has a total yield slightly below that of last year and is now being harvested in good condition. Only approximately 50 per cent of our crop is harvested as of the 8th of October but indications are that notwithstanding considerable blight in the fields, the farmer with good hilling and those who top-killed early, are digging a very sound crop.

A large amount of the seed this year is of Foundation A grade or better. The average yield is below that of last year but above our average.

Present indications are for a good demand for our seed from the Southern States of the United States for early fall, in fact from all parts of the states for late fall. It does seem possible that our large seed quota of 2½ million bushels to the United States will be filled by the first of January 1949.

Potatoes grown on the Island in order of volume are Irish Cobblers, Green Mountains, Sebagoes, Katahdins, and lastly a few Sequoias—only a total of 146 acres, and our total seed acreage is 30,000.—E. D. REID.

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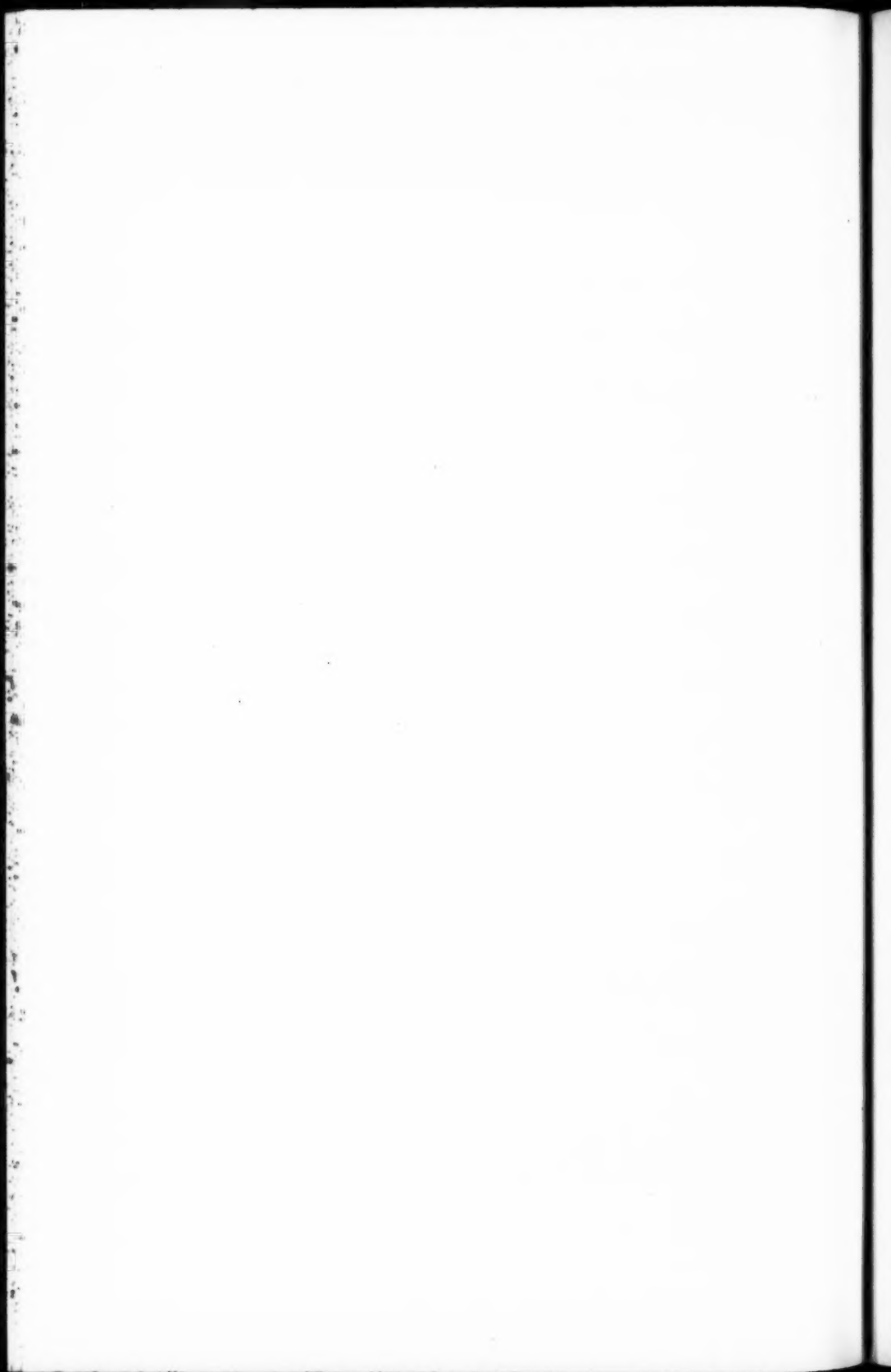
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ERRATUM

In Volumes 23 and 25 the following changes should be made:
Volume 23, May 1946, should read No. 5, instead of No. 4; and Volume
25, July 1948, should read No. 7, instead of No. 6.

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